Shortraker rockfish biomass estimation methods

Report to Plan Team – September 2014

Ingrid Spies and Paul Spencer

Introduction

The November 2013 Plan Team recommended that the authors of the Bering Sea and Aleutian Islands shortraker rockfish assessment provide assessment estimates from both the existing surplus production model and the Survey Averaging Working Group's random effects model, with supporting details, in September 2014.

Prior to 2008, shortraker and rougheye rockfish were assessed with a two-species surplus production model that accounted for potential covariance in catch estimates. In 2008 shortraker rockfish were assessed separately from blackspotted/rougheye rockfish due to the development of an age-structured model for blackspotted/rougheye rockfish. The shortraker rockfish assessment was conducted with Tier 5 methods, in which a non-age-structured model was applied to a time series of survey biomass estimates to obtain the current estimated biomass, and an exploitation rate is then applied to the estimated biomass to obtain the ABC and OFL. This methodology was used until 2012, when a surplus production model was applied to a time series of survey biomass estimates to obtain the current estimated biomass. An exploitation rate was then applied to the estimated current biomass to obtain the ABC and OFL. The 2012 full assessment can be found at http://www.afsc.noaa.gov/REFM/docs/2012/BSAIshortraker.pdf. In 2013 the authors proposed that a random effects model be applied to estimate biomass. This document compares that model with estimates based on the surplus production model.

Analytic Approach

The random effects model and the surplus production model were applied to Aleutian Islands survey data for shortraker rockfish.

Random Effects Model

The random effects (RE) model is an approximation to the Kalman Filter approach. The process errors (step changes) from one year to the next are the random effects to be integrated over and the process error variance is a free parameter. The observations can be irregularly spaced; therefore this model can be applied to datasets with missing data. Large observation errors increase errors predicted by the model, which can provide a way to weight predicted estimates of biomass (http://www.afsc.noaa.gov/REFM/stocks/Plan_Team/2012/Sept/survey_average_wg.pdf).

This information is distributed solely for the purpose of pre-dissemination peer review under applicable information quality guidelines. It has not been formally disseminated by the National Marine Fisheries Service and should not be construed to represent any agency determination or policy.

Surplus Production Model

A simple surplus production model, the Gompertz-Fox model, was used to model the shortraker rockfish population, and the Kalman filter provided a method of statistically estimating the parameter values (Spencer and Rooper 2012). The model was implemented in the software program AD Model Builder. The Gompertz-Fox model (Fox 1970) describes the rate of change of stock size as

$$\frac{dx}{dt} = ax(\ln(k) - \ln(x)) - fx \tag{1}$$

where x is stock size, k is carrying capacity, and f is fishing mortality. The model is mathematically equivalent to a model of individual growth developed by Gompertz, and describes a situation where stocks at low sizes would show a sigmoidal increase in stock size to an asymptote. The Gompertz-Fox model can be derived from the Pella-Tomlinson model (Pella and Tomlinson 1969) by taking the limit as n (the parameter controlling the location of the peak of the production curve) approaches 1. The peak of the production curve occurs at approximately 37% of the carrying capacity, in contrast to the logistic model where the peak occurs at 50% of the carrying capacity. The Gompertz-Fox model was chosen for this analysis because it is a simple model that offers some information on growth rate and carrying capacity, and it is easily transformed into a linear form suitable for the Kalman filter (Thompson 1996). Under the Gompertz-Fox model, the rate of change of yield is modeled as $y = fx$, and the f level corresponding to the maximum sustainable yield (MSY) is equivalent to the growth parameter a. Equilibrium biomass (b) is

$$b = ke^{-f/a} \tag{2}$$

and the equilibrium stock size corresponding to MSY, B_{msy}, is k/e.

Results and Discussion

Survey estimates of shortraker rockfish biomass are available from 1991, 1994, 1997, 2000, 2002, 2004, 2006, 2010, and 2012. Coefficients of variation for those estimates range from 0.19 to 0.58 (Figure 1). The surplus production model estimates of biomass between 1980-2012 from the 2012 shortraker rockfish assessment (Spencer and Rooper 2012) are shown in Figure 2. This method does not provide estimates of uncertainty. The random effects model biomass estimates are shown in Figure 3. CVs are generally smaller than survey values, ranging from 0.17-0.33. Random effects estimates of biomass fall within the 95% confidence intervals from survey estimates (Figure 4). The random effects and surplus production model provide very similar estimates of biomass (Figure 5). The surplus production model does not always fall within the 95% confidence intervals from the survey data (e.g. 2002, 2006).

Results indicate that the random effects model and the surplus production model produce similar estimates of biomass that are generally within the 95% confidence intervals from survey data. The random effects model is preferred by the authors because it provides estimates of uncertainty and does not fall outside the 95% confidence intervals from survey data. The authors recommend the use of the random effects model for estimation of shortraker rockfish biomass in the 2014 and future stock assessments.

References

Fox, W.W. 1970. An exponential surplus-yield model for optimizing exploited fish populations. Transactions of the American Fisheries Society 99:80-88.

Pella, J.J. and P.K. Tomlinson. 1969. A generalized stock production model. Bulletin of the Inter-American Tropical Tuna Commission 13:419-496.

Spencer, P. and Rooper, C. 2012. Assessment of the Shortraker Rockfish stock in the Bering Sea/Aleutian Islands. North Pacific Fishery Management Council. http://www.afsc.noaa.gov/REFM/Docs/2012/BSAIshortraker.pdf. [accessed September 2014].

Thompson, G.G. 1996. Application of the Kalman Filter to a stochastic differential equation model of population dynamics. *In* Statistics in Ecology and Environmental Monitoring 2: Decision Making and Risk Assessment in Biology, D.J. Fletcher, L. Kavalieris, and B.J. Manly (eds.), 181-203. Otago Conference Series No. 6. University of Otago Press, Dunedin, New Zealand.

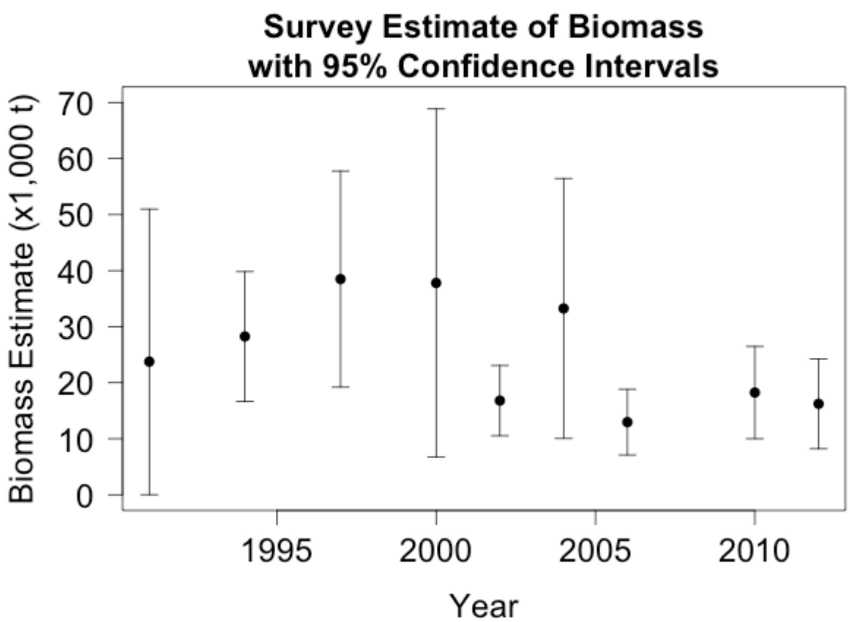

Figure 1. Survey estimate of shortraker rockfish biomass based on the Aleutian Islands survey, with 95% confidence intervals.

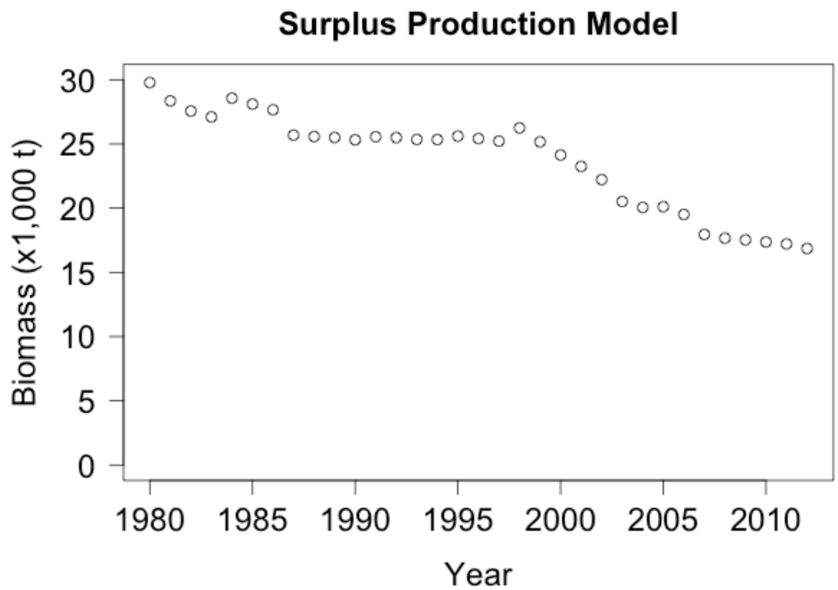

Figure 2. Biomass estimate of shortraker rockfish in the Bering Sea and Aleutian Islands management area, based on the surplus production model from 1980-2012 (Spencer and Rooper 2012).

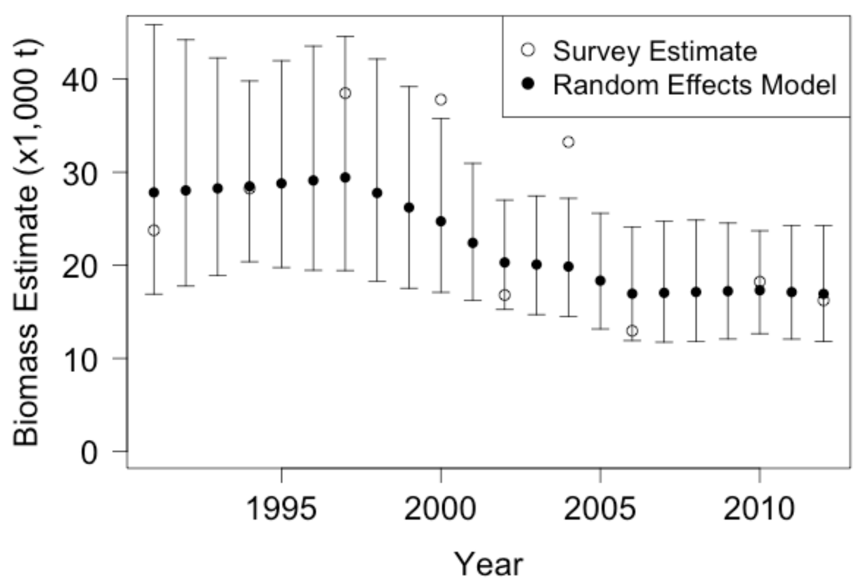

Figure 3. Biomass estimate of shortraker rockfish in the Bering Sea and Aleutian Islands from the random effects model, with 95% confidence intervals, and the survey.

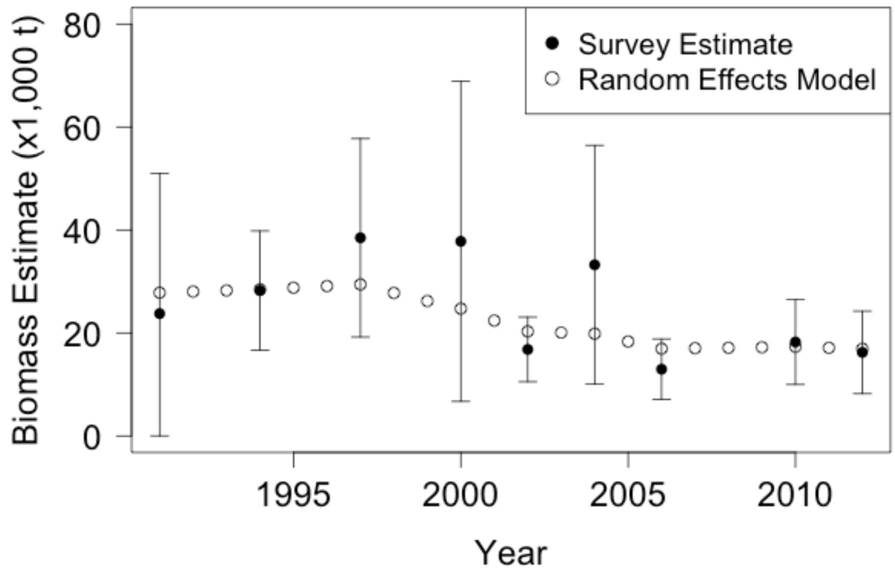

Figure 4. Biomass estimate of shortraker rockfish in the Bering Sea and Aleutian Islands from the survey and random effects model, with 95% confidence intervals on the survey data.

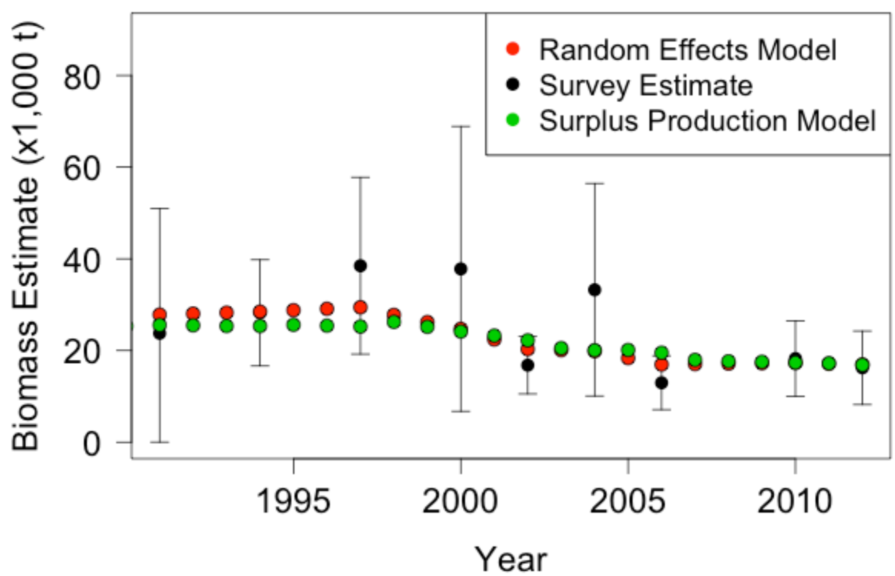

Figure 5. Biomass estimates of shortraker biomass using three methodologies: survey estimate with 95% confidence intervals, random effects model, and surplus production model.